MULTIPATH ROUTING PROTOCOL FOR MANET: APPLICATION TO H.264/SVC VIDEO CONTENT DELIVERY

Jiazi Yi, Benoît Parrein, Dan Radu

MULTIPATH ROUTING PROTOCOL FOR MANET: APPLICATION TO H.264/SVC VIDEO CONTENT DELIVERY

Jiazi YI[1,2], *Benoît PARREIN*[1] *and Dan RADU*[1,3]

[1]Université de Nantes, IRCCyN, CNRS UMR 6597, Polytech'Nantes, France
[2]Hipercom@LIX, École Polytechnique, Palaiseau
[3]Technical University of Cluj-Napoca, Romania
Email: jiazi@jiaziyi.com benoit.parrein@univ-nantes.fr dan.radu@aut.utcluj.ro

ABSTRACT

Multi-Path OLSR is an extension of the single path routing protocol OLSR. The QoS has been demonstrated in simulation and testbed. In this paper, we attempt to confirm those results at the application layer specially for critical applications as video services over wireless networks. The standard H264/SVC is chosen for its enormous potential in video delivery in lossy networks. Still vulnerable to packet losses, we combine the scalable source coding to an Unequal Error Protection (UEP) scheme in order to improve a simple Quality of Experience (QoE) measurements i.e PSNR. In a new simulation framework called *SVCEval*, the combination of path diversity and scalable protection insures a significant 2 dB gain in QoE for sensitive contents and mobile scenarios in comparison with just MP-OLSR. Within the same context, single path strategy delivers non acceptable video services as soon as nodes are mobile.

Index Terms— H.264/SVC, ad hoc network, multipath routing, MP-OLSR, QoS, QoE

I. INTRODUCTION

With the rapid development of the wireless network technology, the specifications on wireless LAN like 802.11a/b/g are becoming popular for video transmission. Larger networks with longer ranges can be achieved by multi-hop transmission, i.e. Mobile Ad Hoc NETwork technology (MANET).

The dynamic topology and the unpredictable wireless environment are great challenges for routing the data over MANETs. A lot of routing protocols have been proposed, such as Optimized Link State Routing (OLSR [2]) and Dynamic Source Routing (DSR [3]). However, those routing protocols still suffer from frequent route failures and make it impossible to forward packets reliably. It is even more difficult to provide video services which require large bandwidth and strong delay constraints in MANETs. So the multipath scheme is proposed to provide higher aggregate bandwidth and fault tolerance. By employing techniques such as multichannel [4] or exploring the diversity of paths [5], the algorithms could prevent interference and improve network performance over heterogeneous networks (802.11, 3G, bluetooth, etc.).

In our work [1], the MP-OLSR is introduced as an multipath extension of OLSR protocol. The new protocol is evaluated in both simulation and real testbed, and the results reveal that the multipath routing outperforms the single path routing, especially in dense and mobile networks with high network load. However, the tests are only performed with regular data transmission, and without results on real multimedia service, especially the ones with critical QoS constraint.

In the literature, there have been a lot of work to improve the quality of video transmission. In [6], the multiple description coding (MDC) and multiple path transport are combined for video and image transmission in MANET. In [7], the author presents a multisource streaming approach to increase the robustness of real-time video transmission in MANET. Another UEP scheme is proposed in [8] based on the estimation of the overall distortion of decoder reconstructed frames due to enhancement layer truncation, drift/error propagation and error concealment in the H.264/SVC. Our previous work in [9] also discussed the priority image and video transmission. The works introduced above mainly focus on the resilient coding of the video frames. Simple network models and routing protocols are used to validate the results.

In this paper, we are specially interested in Scalable Video Coding (SVC) over MANET. We propose the multipath routing approach with UEP to transmit H.264/SVC video stream over MANET to improve the video quality at the receiver. Multipath Optimized Link State Routing (MP-OLSR) is used as routing protocol. It is a multipath extension of OLSR, and can generate multiple node-disjoint or link-disjoint paths by using *Multipath Dijkstra Algorithm*. Based on the multipath routing and the scalable information provided by SVC, the UEP code with Maximum Distance Separable (MDS) property is applied to improve the Quality of Experience (QoE) of video transmission. To evaluate the transmission of H.264/SVC, a video evaluation framework, *SVCEval*, is proposed to simulate the video bitstream over different kinds of networks. The simulation is taken in a MANET with different mobility and topology changes.

The remainder of the paper is organized as follows. We recalled our MP-OLSR protocol and the UEP scheme in section II. In section III, simulation and performance evaluation are performed with an introduction of the *SVCEval* framework. Finally, we conclude this paper in section IV.

II. MULTIPATH OLSR FOR PRIORITY ERROR CORRECTION

II-A. Multipath Optimized Link State Routing

The MP-OLSR can be regarded as a kind of hybrid multipath routing protocol which combines the proactive and reactive features. It sends out *HELLO* and *TC* messages periodically to detect the network topology. However, MP-OLSR does not always keep a routing table. It only computes the multiple routes when data packets need to be sent out. The functionality of MP-OLSR has four parts: *topology sensing*, *route computation*, *route recovery* and *loop detection*.

The *topology sensing* is to make the nodes aware of the topology information of the network. This part benefits from *MPRs*. To get the topology information of the network, the nodes use *Topology sensing* which includes link sensing, neighbor detection and topology discovery, just like OLSR [2].

The *route computation* uses the *Multipath Dijkstra Algorithm* [10] to calculate the multipath based on the information obtained from the *topology sensing*. The source route (all the hops from the source to the destination) is saved in the header of the data packets. The algorithm makes use of two cost functions to discover the node-disjoint or link-disjoint multiple paths according to their values.

The *topology sensing* and *route computation* make it possible to find multiple paths from source to destination. In the specification of the algorithm, the paths will be available and loop-free. However, in practice, the situation will be much more complicated due to the change of the topology and the instability of the wireless medium. So *route recovery* and *loop detection* are also proposed as auxiliary functionalities to improve the performance of the protocol. The *route recovery* effectively reduces the packet loss, and the *loop detection* is used to avoid potential loops in the network.

More details about the routing protocol can be found in our previous work in [1]. From the results obtained from the simulation and testbed, we can conclude that the Multipath OLSR can effectively improve the data delivery ratio up to 20% in mobility and high data rate scenarios and reduce the end-to-end delay by a factor three with much lower standard deviation. All of these measurements are obtained without introducing extra routing traffic. The protocol has been submitted to Internet Engineering Task Force (IETF) as Internet Draft [11].

II-B. Unequal Error Protection Coding for Multipath Routing

A (n, k, d)-MDS code refers to k user packets that are encoded into n redundant packets, such that with the reception of any $(n - d + 1)$ of the n redundant packets, the k user packets can be recovered. Any MDS code can be employed here. We can use, for instance, Finite Radon Transform (FRT), which is a discrete data projection methods that are exactly invertible. Each element of the coded projection is computed using simple addition operations. For detailed information, please refer to our latest results in [12]. Based on this assumption, we will use in the rest of this paper the term of projection to describe user packet or redundant packet knowing that this MDS code can de constructed in a systematic manner.

At the source coding stage, a wide range of scalability (spatio-temporal and quality) can be achieved by using SVC. It allows removal of parts of the bit-stream and still get reasonable coding efficiency with reduced temporal, spatial or SNR resolution. This feature is very attractive for unstable network transmission because we can focus on the more important scalable layers to improve the final video quality. The protection of these layers can be naturally achieved by using UEP based on FEC code described above.

Compared to the equal forward error correction, which applies equal redundancy to all the packets, the UEP can give a good balance between the error correction and network load by focusing on the most important packets. Original packets with higher priority can be assigned with higher redundancy and the coded projections can be distributed into disjoint multiple paths. So even when some of the projections are lost because of route failure, it is still possible to recover the original packet, as illustrated in figure 1.

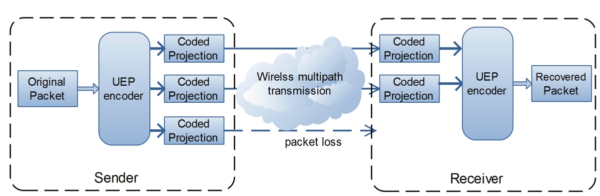

Fig. 1. Multipath transmission with UEP based on FRT algorithm

To make use of priority FEC, it is important to know the priority of the packets in the video bitstream. For H.264/SVC bitstream, the scalability structure is defined by three syntax elements: *dependency_id*, *quality_id*, and *temporal_id*. The syntax element *dependency_id* denotes the spatial scalability inter-layer coding dependency hierarchy. The *quality_id* designates the quality level hierarchy of medium granularity scalability (MGS). The *temporal_id* indicates the temporal scalability hierarchy or the frame rate.

However, although those three variables can provide scalable information of the bitstream, no assumption on a relation between the priority of the packets and the values of *dependency_id*, *quality_id*, or *temporal_id* is explicitly made in the SVC draft.

To confirm the priority of different scalable layers, a packet-loss simulation is launched (more details about the video codec configuration can be found in section III-B). A packet-loss simulator is made so that we can define the packet loss from a specified scalable layer (temporal, spatial or quality). Then the PSNR of the achromatic Y component is measured to compare the packet loss from which layer has more impact on the video quality, which corresponds to higher priority.

Figure 2 presents the impact of packet loss from different temporal layer to the quality of the video (*t1* stands for the packet loss from layer with *temporal_id* equals *1*, etc.). As shown in the figure, with the same percentage of packet loss (over total packets) from different temporal layers, the packet loss from *t1* has the most impact on the video quality, and then is the *t2*, etc. The packet loss from *t4* and *t5* has the least impact.

The results indicate that with our current configuration of JSVM codec, the *t1* packets have the highest priority, and the *t4* and *t5* packets have the lowest priority. This hierarchy will be considered in the following for priority coding.

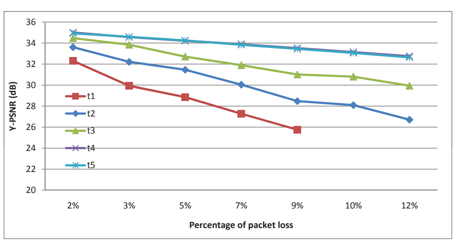

Fig. 2. The impact of packet loss from different temporal layer to the quality of the *football* video

III. PERFORMANCE ANALYSIS

III-A. Evaluation Framework for H.264/SVC

Currently, most of the study in H.264/SVC video quality and error concealment such as in [13] is based on error patterns. This scheme can define a specified loss rate in the bitstream and it is very useful and efficient for the error resilient study. However, it is not sufficient if we want to introduce reality and to simulate the video communication over any network architecture including MANET.

To evaluate the H.264/SVC transmission over different kinds of networks, especially ad hoc networks, we proposed an evaluation framework *SVCEval* as shown in figure 3. It is based on the SVC reference software JSVM and makes use of the Qualnet simulator for the network simulation.

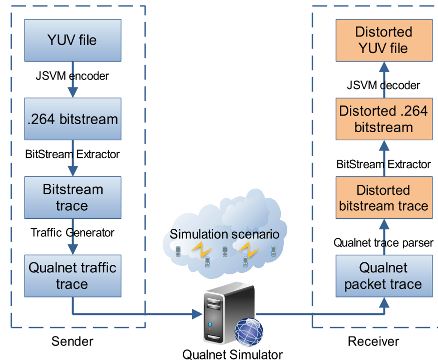

Fig. 3. The evaluation framework *SVCEval* for H.264/SVC

At the video sender, the YUV file is encoded by the JSVM encoder, and the .264 bitstream is generated. Then the *BitStreamExtractor* is used to generate the bitstream trace from the given bitstream. A *Traffic Generator* is then written to generate the input traffic trace file for Qualnet simulation. The simulator will take the traffic trace file and run the simulation according the configuration of scenarios to simulate different kinds of networks.

At the video receiver, a packet trace file is produced by the simulator. The packet trace file records all the operation on each packet in each node and each layer (so normally hundreds of MBytes). A *QualnetTraceParser* is developed to analyse the trace to detect which packets are lost and which packets are properly received. For real-time transmission, we can set a delay threshold to discard the packets that timed out. The trace parser can generate the *distorted bitstream trace*, and then we use the *BitstreamExtractor* and *JSVM decoder* to have the distorted YUV file after the video transmission. Then we can evaluate the quality of video with different metrics such as PSNR or Mean Opinion Score (MOS).

III-B. Test Conditions and Network Scenario

To demonstrate the performance of multipath routing of the H.264/SVC video transmission over ad hoc networks, we performed the simulation based on the evaluation framework proposed. The *football* sequence with high and irregular motion is used as a sample. The configuration of the JSVM codec is as follows.

- JSVM 9.8 with error concealment.
- Two layers with based layer QCIF@30Hz and enhancement layer CIF@30Hz.
- *SliceMode* is set to *fixed number of bytes per slice*, with *SliceArgument* set to 1000.

The UEP scheme is applied to the video stream. The layers with *temporal_id* 1 and 2 are encoded using systematic code.

Each time at the sender, the coder will buffer 2 packets, and generate 3 projections. At the receiver, the decoder needs 2 projections to recover the original packets. The rest of the layers are not coded and transmitted in its original form (i.e. not protected). The layer with *temporal_id* 0 are regarded as *non discardable* packets, so we assume those packets are transmitted along reliable channel.

Of course, redundant allocation can be different and set in an optimal way. For this purpose, we can consider increments of quality provided by each layer associated with the probability to receive this quality layer in order to maximize expectation of the overall quality (see by example [9] for more details). In this paper, we consider just static redundant allocation for illustrating the interest of multiple path both in QoS and QoE.

For the network configuration, Qualnet 5.0 is employed for network simulation. The detailed parameters are listed in Table I for the purpose of repeatability.

Table I. Simulator Parameter Set

Parameter	Values
Simulator	Qualnet 5.0
Simulation area	1500m $\times$ 1500m
Number of nodes	80
Mobility	RWP, max speed 0-10m/s
Application Packet size	512 bytes
Transmission Interval	0.1 s
Traffic	1 video source
Background traffic	4 CBR
MAC Protocol	IEEE 802.11
Physical Layer Model	PHY 802.11b
Pathloss Model	Two Ray Ground
Shadowing Model	Constant
Shadowing Mean	4.0 dB
Transmission Range	270m
Data Rate	11Mbps

III-C. Simulation Results

Figure 4 compares the delivery ratio of OLSR and MP-OLSR with or without UEP coding. The four configurations have almost the same performance at low speed, but the delivery ratio of single path routing (labelled OLSR and OLSR_FEC in the figure) decreases quickly as the mobility increases. This is because as the links become more unstable, the MP-OLSR could take benefits from the multipath routing.

The UEP could slightly increase the delivery ratio of MP-OLSR (about 1%), but not significant for OLSR. This is because: firstly, in the network, the packet loss is continuous most of the time because of congestion or route failure. With multiple paths, the projections are distributed in the disjoint paths and forwarded to the destination independently. The FEC can still work even some of the routes failed as illustrated in figure 3. Secondly, it is inevitable that the FEC coding will increase the network load even priority coding strategy is employed because the redundancy is added in the packets to protect the data. This will increase the packet loss and maybe results in worse video quality in the end for single path routing (for example, the 5m/s and 6m/s for OLSR_FEC). This problem is less serious for multipath routing because it can provide higher overall bandwidth.

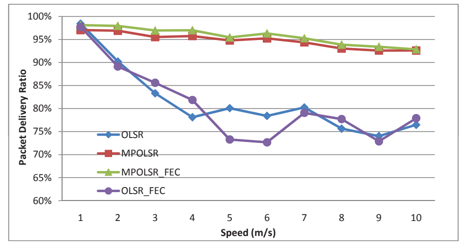

Fig. 4. The delivery ratio of different protocols (with or with out FEC code)

Figure 5 compares the quality of the video transmission of the protocols used above. Compared to OLSR, MP-OLSR has worse quality in very low-mobility scenarios (1m/s and 2m/s). As the node speed increases, the quality of OLSR drops quickly and MP-OLSR outperforms OLSR. This result is consistent with the conclusion from our previous work that the single path routing might have better delivery ratio than MP-OLSR in the network with very less topology changes. However, in these low-mobility scenarios, the MP-OLSR can make use of single path also because the MP-OLSR is compatible with OLSR [1].

Although the improvement of the MP-OLSR with priority FEC coding *i.e.* MPOLSR_FEC in delivery ratio is not obvious, the MPOLSR_FEC can effectively improve the QoE by 2 dB on average. It is because the packets with high priority (*temporal_id* equals *1* or *2*) are better protected with UEP. The overhead produced by UEP is 15% with our static configuration.

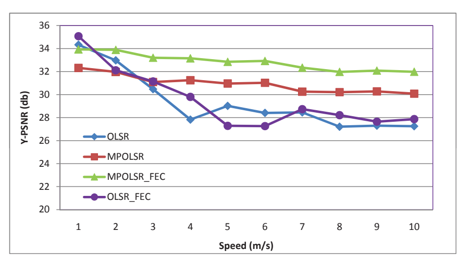

Fig. 5. The quality of video transmission through the different protocols (with or without FEC code)

Figure 6 presents the screenshots of three frames extracted from one simulation, at the maximum speed of 4m/s. The MP-OLSR with UEP provided the best video QoE. OLSR suffers from the most packet losses. The frames displayed by OLSR are delayed because the *frame copy* error concealment method is used. For single path routing, the delivered video content is simply not acceptable.

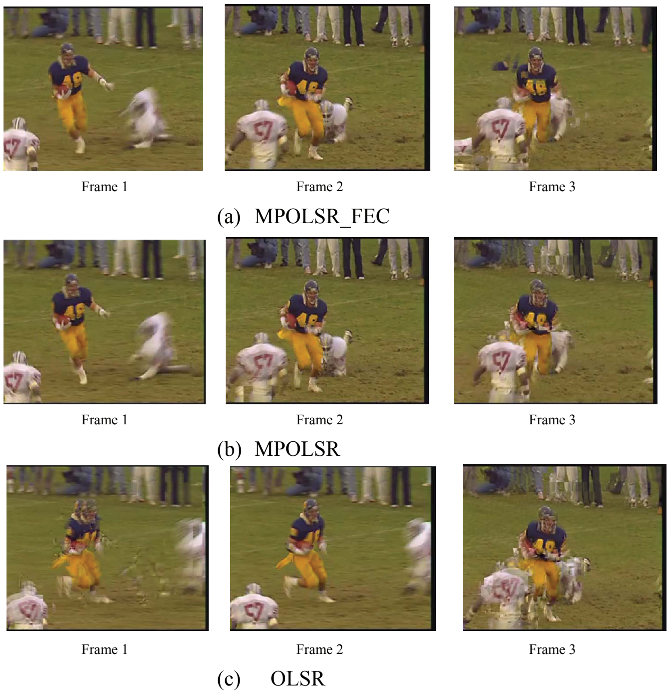

Fig. 6. Screenshots of the *football* video sequence from scenario with maximum speed 4m/s

IV. CONCLUSION

In this paper, we proposed a method to deliver H.264/SVC video stream over MANET by using a multipath routing protocol, called MP-OLSR. With UEP, the data with higher priority can be better protected over the packet lossy networks. The *SVCEval* is built as an evaluation framework for H.264/SVC video network transmission. Based on the JSVM and the Qualnet network simulator, it can provide great flexibility and more realistic scenarios by simulating the video transmission over different kinds of networks.

The results from the simulation show that the multipath routing is more adapted to network topology changes. And with UEP, the QoE can be significantly improved (by 2 dB in Y-PSNR in our experiment scenarios) without introducing much network load. This result confirms the QoS observation that we did in a previous study [1] regarding multiple paths. We expect to obtain similar trend in our experimental testbed in a foreseeable future. More relevant QoE measurements will be considered on a same time.

V. REFERENCES

[1] Jiazi Yi, Asmaa Adnane, Sylvain David, and Benoît Parrein, "Multipath optimized link state routing for mobile ad hoc networks," *Ad Hoc Networks*, vol. 9, no. 1, pp. 28–47, 2011.

[2] Thomas Clausen and Philippe Jacquet, "IETF Request for Comments: 3626, Optimized Link State Routing Protocol OLSR," October 2003.

[3] David B. Johnson, Y. Hu, and David A. Maltz, "IETF Request for Comments: 4728, The Dynamic Source Routing Protocol (DSR) for Mobile Ad Hoc Networks for IPv4," February 2007.

[4] Hamid Gharavi, "Multichannel mobile ad hoc links for multimedia communications," *Proceedings of the IEEE*, vol. Vol. 96, Issue:1, pp. 77–96.

[5] Wolfgang Mhlbauer, Steve Uhlig, Anja Feldmann, Olaf Maennel, Bruno Quoitin, and Bingjie Fu, "Impact of routing parameters on route diversity and path inflation," *Computer Networks*, vol. 54, no. 14, pp. 2506 – 2518, 2010.

[6] Doo-Man Chung Nitin Gogate, Shivendra S. Panwar, and Yao Wang, "Supporting image and video applications in a multihop radio environment using path diversity and multiple description coding," *IEEE Transactions on Circuits and Systems for Video Technology*, vol. 12, pp. 777–792, September 2002.

[7] Thomas Schierl, Karsten Ganger, Cornelius Hellge, and Thomas Wiegand, "SVC-Based Multisource Streaming over Robust Video Transmission in Mobile ad hoc Networks," *IEEE Wireless Communications*, pp. 96–103, October 2006.

[8] E. Maani and A.K. Katsaggelos, "Unequal error protection for robust streaming of scalable video over packet lossy networks," *IEEE Transactions on Circuits and Systems for Video Technology*, vol. 20, pp. 407–416, March 2010.

[9] Benoît Parrein, Fadi Boulos, Patrick Le Callet, and Jean Pierre Guédon, "Priority image and video encoding transmission based on a discrete radon transform," in *IEEE 16th International Packet Video Workshop*, Lausanne, Switzerland, 2007.

[10] Jiazi Yi, Eddy Cizeron, Salima Hamma, and Benoit Parrein, "Simulation and performance analysis of MP-OLSR for mobile ad hoc networks," in *IEEE WCNC: Wireless Communications and Networking Conference*, Las Vegas, USA, June 2008.

[11] A. Szwabe, Ed. A. Nowak, E. Baccelli, J. Yi, and B. Parrein, "IETF Internet Draft, Multi-path for Optimized Link State Routing Protocol version 2, draft-szwabe-manet-multipath-olsrv2-01," November 2010.

[12] Nicolas Normand, Imants Svalbe, Benoît Parrein, and Andrew Kingston, "Erasure Coding with the Finite Radon Transform," in *IEEE Wireless Communications & Networking Conference*, Sydney, Australia, 2010.

[13] Yi Guo et al., "Error resilient coding and error concealment in svc," *IEEE Transactions on Circuits and Systems for Video Technology*, vol. 19, 2009.